



U.S. Department of Energy  
Energy Efficiency and Renewable Energy

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# Advancement of High Temperature Black Liquor Gasification (DE-FC26-04NT42259)

**DOE OBP Thermochemical Platform Review Meeting  
June 7-8, 2005**

**Craig Brown  
Weyerhaeuser**



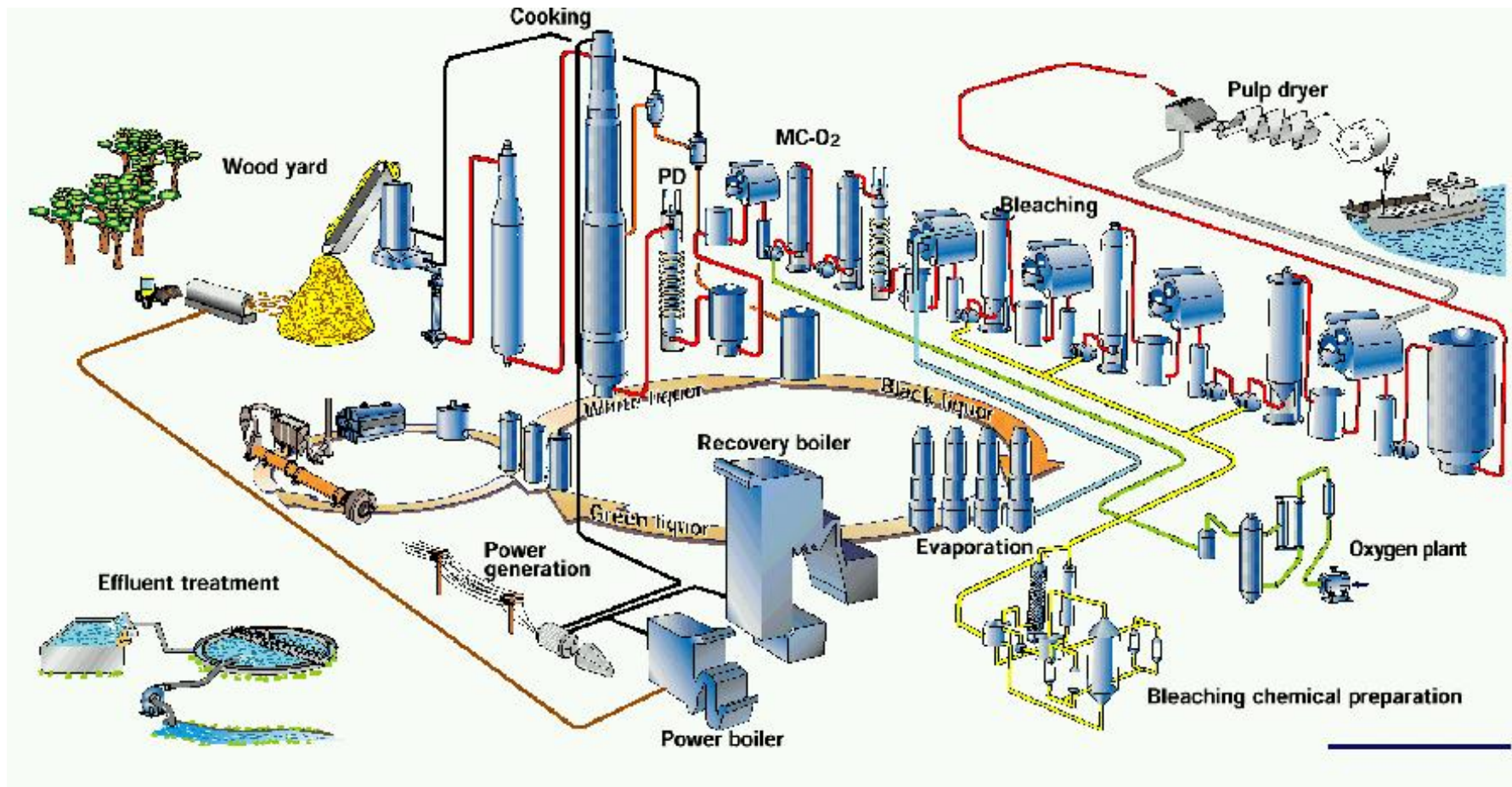
## *biomass program*

- **Project Background**
- **Technical Feasibility and Risks**
- **Competitive Advantage**
- **Project Overview**
  - OBP Pathways/Milestones
- **History and Accomplishments**
- **Plan/Schedule**
- **Critical Issues and Show-stoppers**
- **Plans and Resources for Next Stage**
- **Summary**



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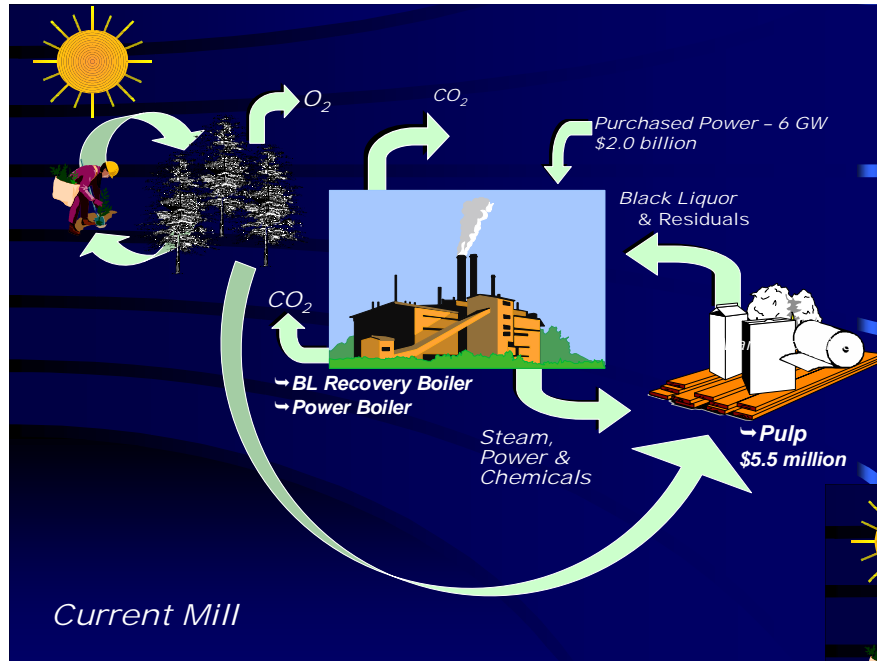
## Pulp Mill Process



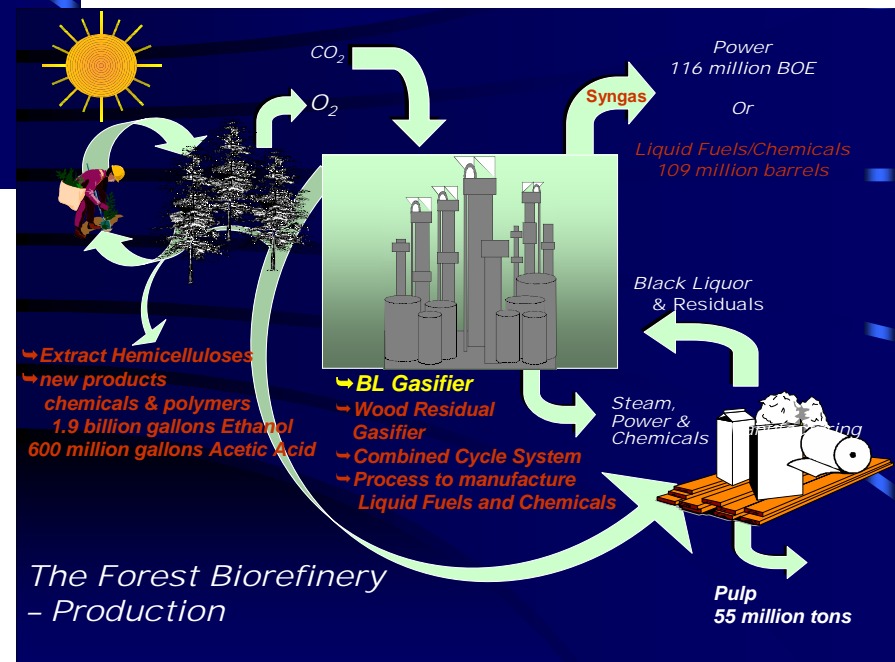


# Project Background

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Black Liquor Gasification is a cornerstone technology for future integrated forest products biorefinery







# Project Background

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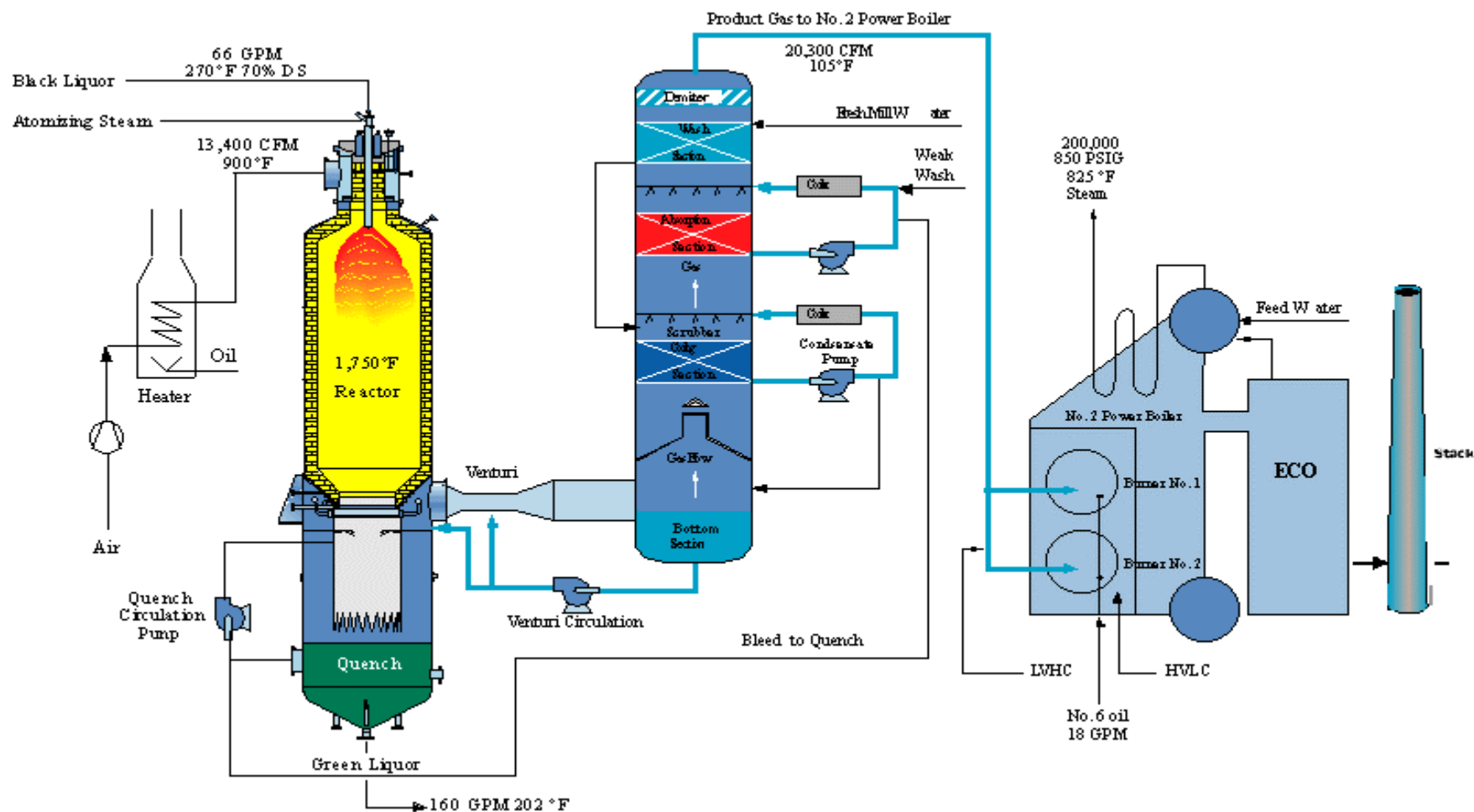
- Operation of New Bern's Chemrec gasifier offers a unique opportunity to advance development of HTBLG technology
- Gasifier started up Dec 1996 – key part of a pulp mill production optimization project
- The “BLG Booster” provides incremental BL processing capacity(~15%) to pulp mill
- Addressed numerous scale-up, process reliability & integration issues over the past eight years





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## CHEMREC® NEW BERN BOOSTER





# Technical Feasibility and Risks

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- New Bern gasifier already operates as a commercially viable “booster” facility
- Utilizing New Bern facility as a “test bed” provides unique opportunity to mitigate HTBLG demonstration risks
  - Conduct long-term continuous trials under “real” process conditions
  - Combine fundamental chemistry analysis and advanced modeling tools to identify solutions to “real” problems
  - Implement & validate practical solutions



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- Problems addressed are common to both atmospheric (“booster”) & pressurized developments, e.g.:
  - Need for advanced modeling capability
  - Addressing process reliability issues related to scaling and plugging in process streams
  - Addressing process integration issues through SCT scrubber development and dregs filterability work
  - Efforts are coordinated with Chemrec’s pressurized HTBLG development project at Pitea, Sweden





# Pathways and Milestones – C-level and Project Milestones

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## Aq Residues

## Perennial Grasses

## Woody Crops

## Pulp and Paper

## Forest Products

6.1.1 Validate reliable and economic performance of gasification of spent pulping liquor

6.1.5 Validate integrated black liquor gasification and causticization process in pulp and paper mill

Project Milestones	Type	Performance Expectations	Due Date
Develop & validate improved HTBLG CFD modeling tools	D	Develop CFD tools for use in design of improved burner system	2/06
Validation & demonstration of improved burner design	D	Reduce gasifier operating temperature by >100 F => Increased refractory life Improved thermal efficiency >10%	7/07
Develop & validate practical solutions to scaling and plugging in process streams	D	Improve process reliability from current 80% to +90%	7/07



# Pathways and Milestones – C-level and Project Milestones

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## Aq Residues

## Perennial Grasses

## Woody Crops

## Pulp and Paper

## Forest Products

6.1.5 Validate integrated black liquor  
gasification and causticization  
process in pulp and paper mill

6.2.3 Validate integrated chemical  
recovery and gas cleanup process at  
pilot scale

Project Milestones	Type	Performance Expectations	Due Date
Evaluation of short contact time scrubber	D	Technical performance specification for SCT scrubber	3/07
Evaluation of green liquor dregs filterability	D	Technical performance specification for green liquor filter	12/06
Demonstrate impact of O2 enrichment	D	Complete field performance trial and report	3/07



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- Project Objective: Utilize the New Bern gasifier as a test bed to advance the state of high temperature BLG development.
  - Task 1 – Develop and “validate” CFD modeling tools for HT entrained flow gasification
  - Task 2 – Use CFD tools to develop an improved BL burner and quench
  - Task 3 – Evaluate and develop practical solutions to process reliability issues
    - Green liquor scaling
    - Process condensate scaling and fouling
  - Task 4 – Evaluate process integration issues
    - Scrubber selectivity and efficiency – slip stream SCT pilot
    - GL dregs filterability
  - Task 5 – Evaluate the impact of O<sub>2</sub> enrichment



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- **Project Partners:**
  - **Chemrec AB:** Technology developer and supplier, responsible for design and implementation of process improvements, experimental spray facility at Pitea.
  - **IPST @ GT:** Develop fundamental understanding of GL & condensate scaling processes, and process integration issues related to GL dregs, tars and oils. Also provide fundamental gasification rate data/equations and BL property data for CFD models.
  - **PSL:** Develop an overall CFD model of the gasifier reactor and use to guide design improvements to burner and quench
  - **Simulent:** Develop detail model of BL nozzles that will be integrated into the reactor CFD model
  - **GTI:** Use advanced gas analytical suite to characterize product gas during process testing periods. (Separate DOE funding)



# History and Accomplishments

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- Contracting Status –
  - A major undertaking for Weyerhaeuser
    - Lack experience with FAR and government contracting
  - Advance patent waiver granted – a key hurdle overcome
  - Subcontracting status
    - IPST@GT: Complete
    - PSL & Simulent: Final terms agreed – executing
    - Chemrec: One outstanding issue, close to resolution



# History and Accomplishments

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- Despite contracting status...
  - Two Project team meetings were held
    - Nov 4-5, 2004 – Project “Kick-off” at IPST in Atlanta
    - Feb 17-18, 2005 – In conjunction with IEA Annex XV in Big Island, VA
  - Key focus: development of better integrated and coordinated work plans
  - Our success depends upon effective interaction between work efforts of project partners





# History and Accomplishments

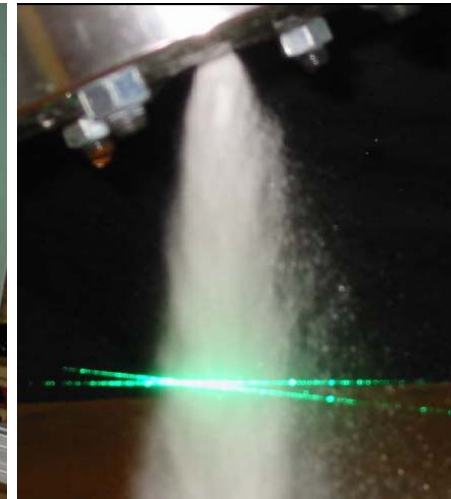
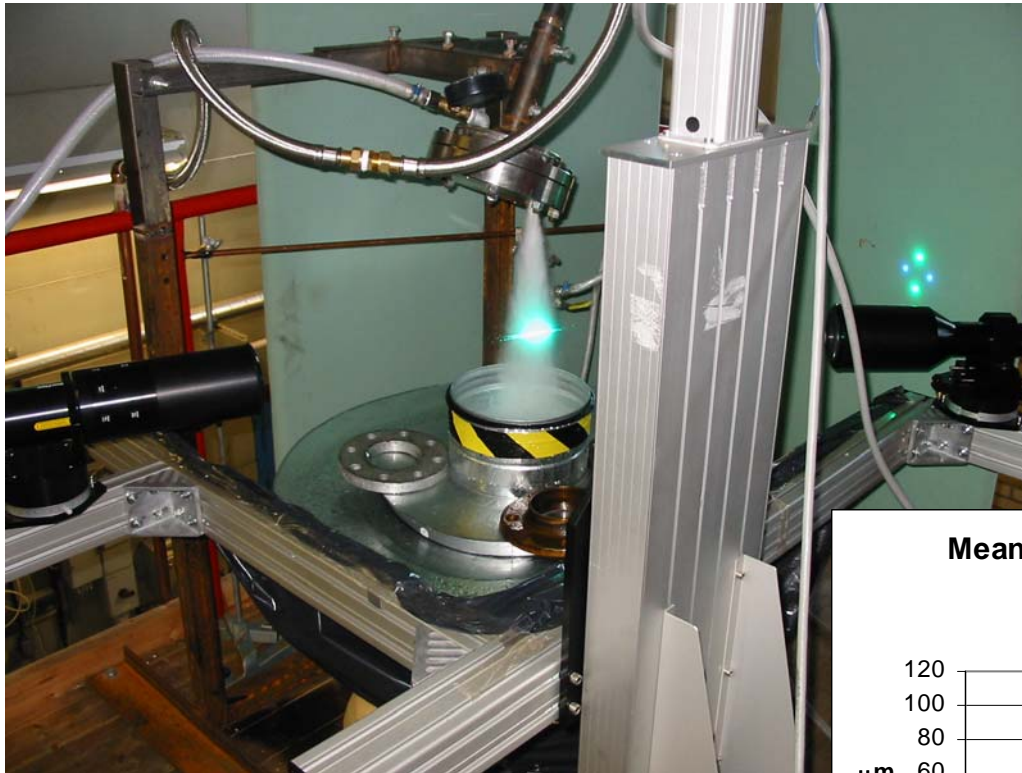
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- Significant progress on CFD model development
  - PSL implemented enhanced rate models based on input from IPST
  - Simulent have demonstrated model of the BL nozzle
  - Chemrec generated spray data at facility in Pitea
  - Simulent demonstrated good agreement between Chemrec experimental data and spray model
  - Simulent and PSL have developed an interface to pass data between nozzle and reactor models
  - Ready to model test matrix

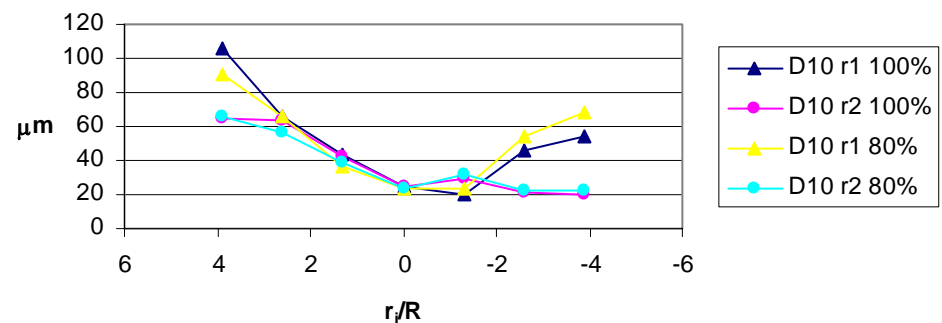


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## Chemrec Experimental Spray Results



Mean diameter along  $r_1$  and  $r_2$  at 100% and 80% flow rates of water



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## Simulent Spray Modeling – Comparison with Pitea Experiments

Location where  
calculated data  
are obtained

(4mm after  
Nozzle Exit)

Location where  
Experimental  
data are read

(100mm after  
Nozzle Exit)

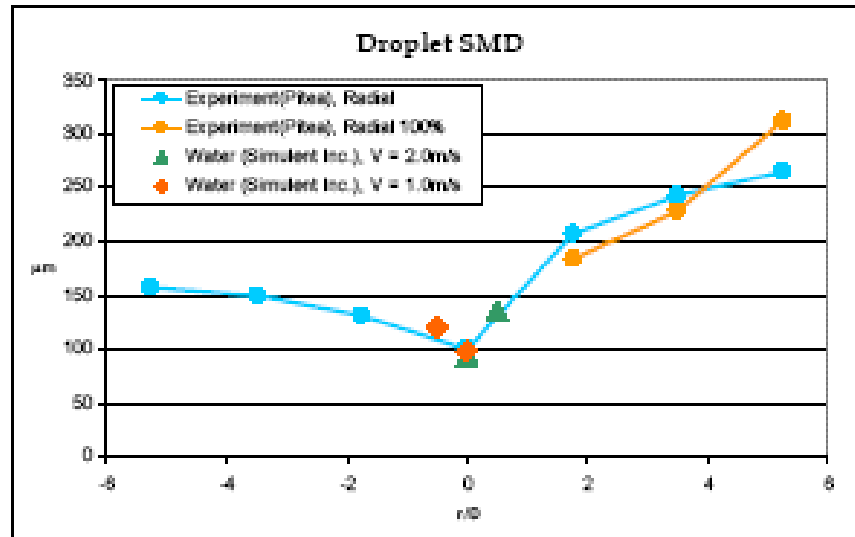
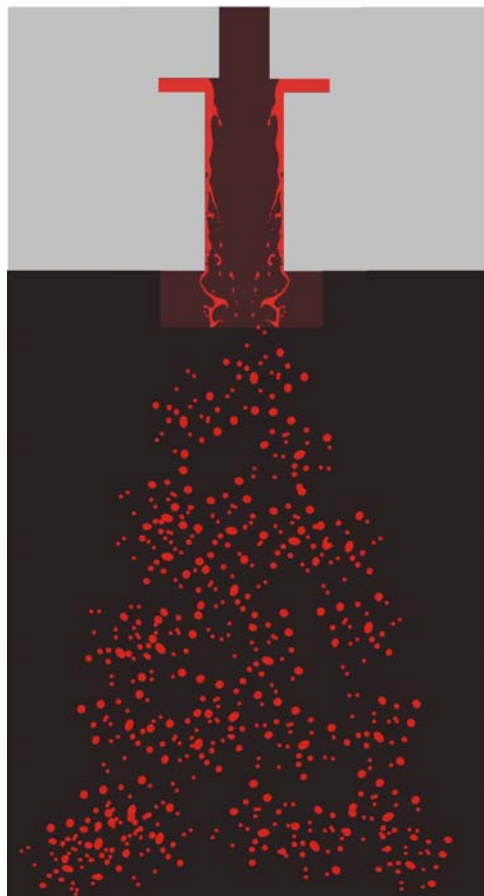


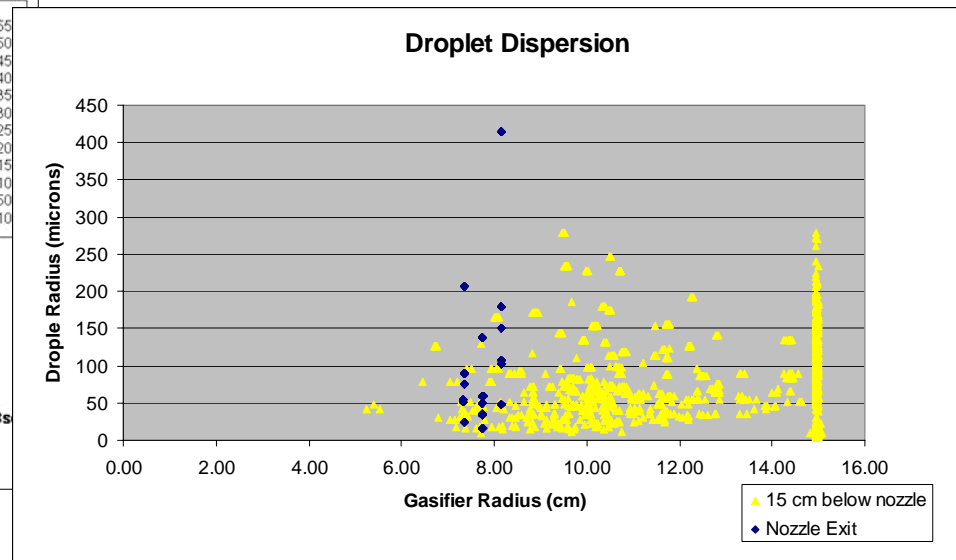
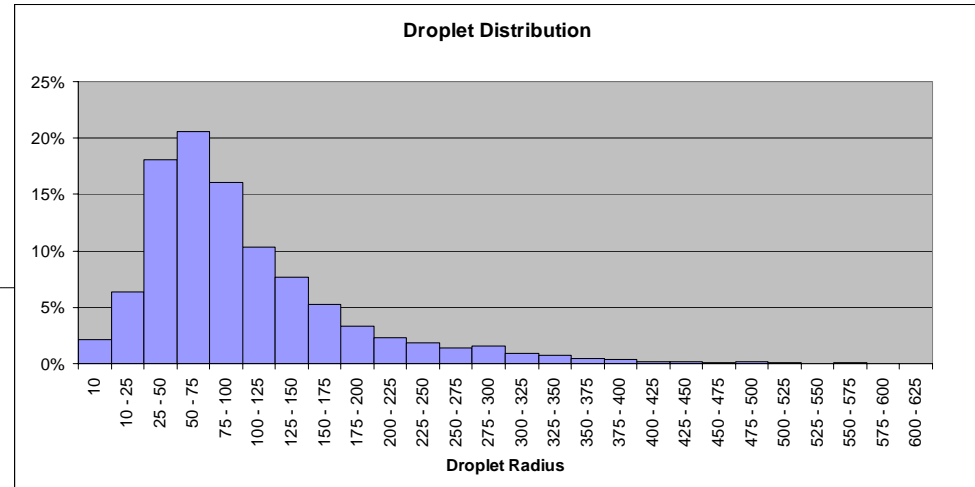
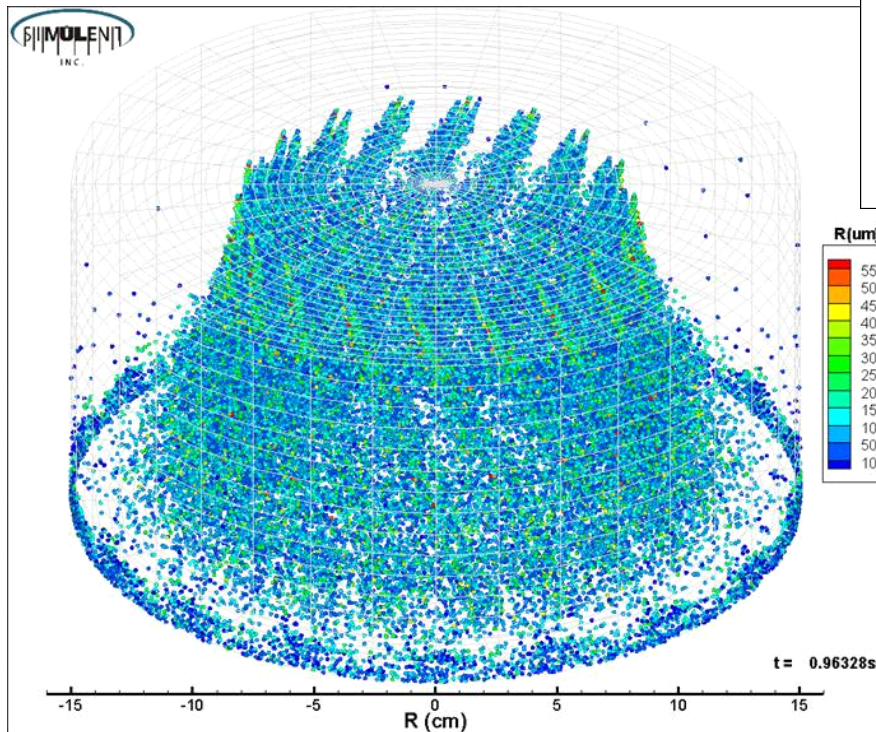
Figure 5- Comparison of black liquor SMD measured at the Energy Technology Centre (Pitea) with Simulent Inc. simulation results.



# History and Accomplishments

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## Simulent -New Bern Nozzle Simulation



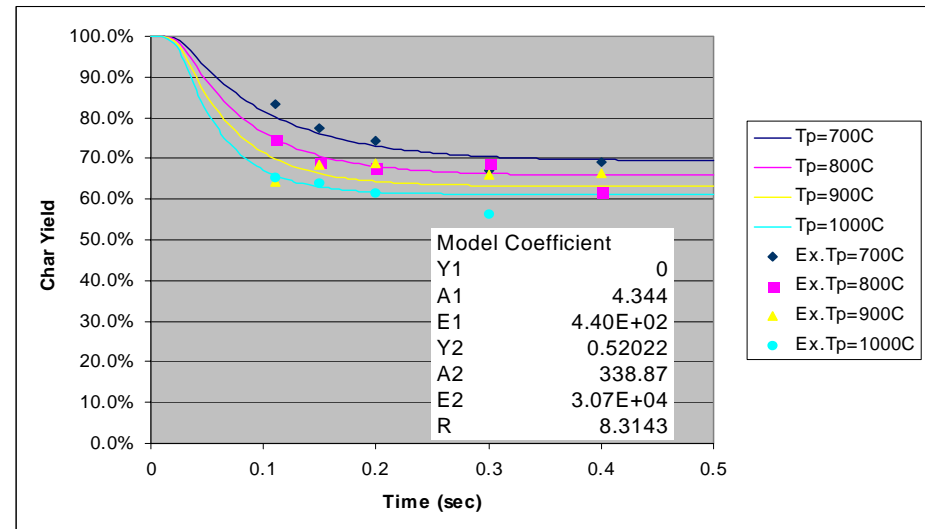
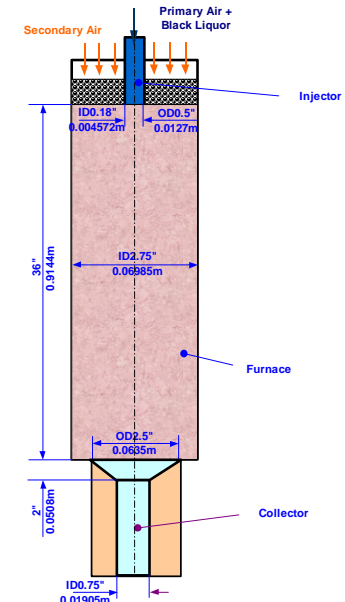


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## PSL/IPST – BLG Model Upgrades

### Char Gasification Model

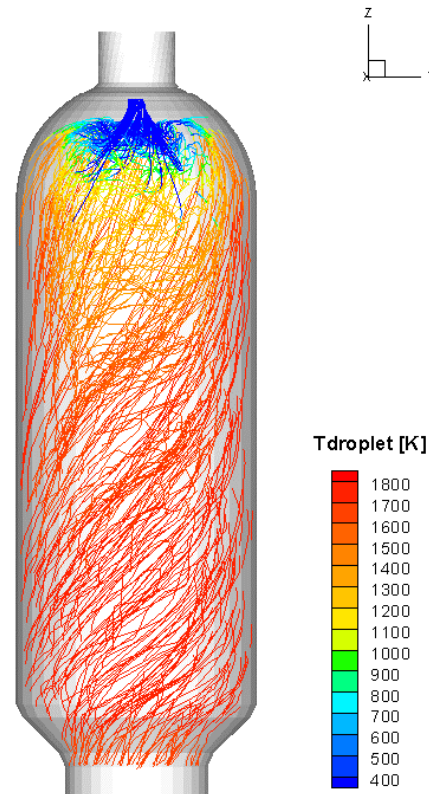
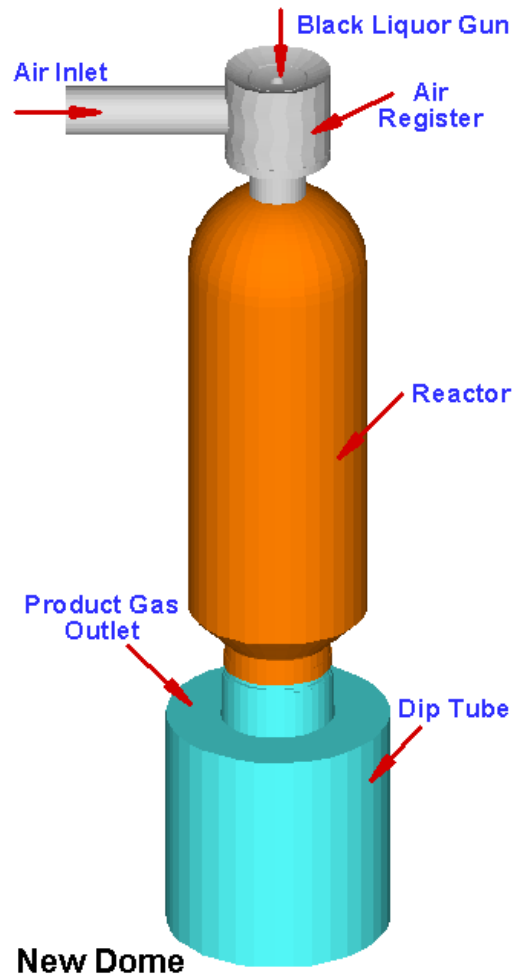
- Inorganic reactions in  $N_2$ 
  - Sulfate reduction, carbonate reduction
    - $r_C = k_1[C]$
    - $k_1 = 8.532 \times 10^3 \exp(-11454/T)$
- Gasification stage
  - $r_C = k_1[C] + k_{\text{gas}}[C]$
- $CO_2$ 
  - $r = 3.1 \times 10^{16} s^{-1} \exp(-48650K/T)[C]$
- $H_2O$ 
  - $r = 2.6 \times 10^{10} s^{-1} \exp(-28000K/T)[C][H_2O]^{0.3}$
  - \* provided by Kristiina Iisa from IPST



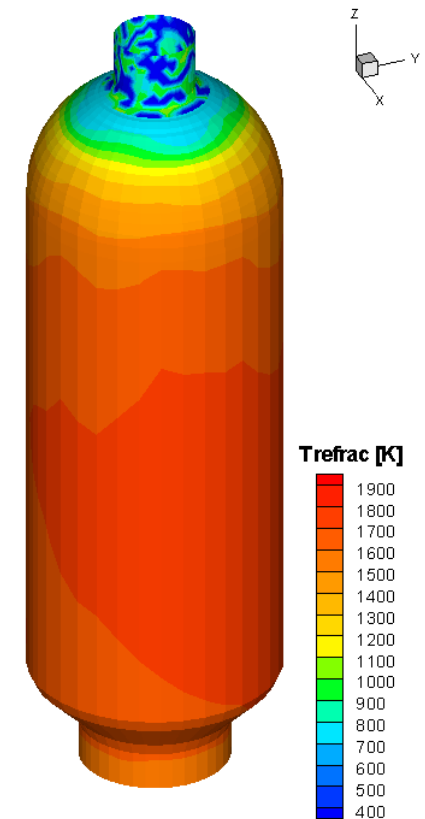


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## PSL New Bern Reactor Modeling



Droplet Trajectory and Temperature  
(Windows inside air register closed)



Refractory Temperature  
(Windows inside air register closed)





# History and Accomplishments

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- Phase I testing is underway
  - Test plan developed – ready for implementation
  - Objective: Develop “test matrix” data for “correlation” with CFD model
  - Schedule:
    - May 21-June 10:
      - GTI set-up & troubleshoot analytical suite
      - IPST finalize sampling plan
    - June 13 – 24: Test Matrix



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- Phase I: Development of technical information and basis (Nov. 2004 – Feb 2006)
  - 3-4 month delay due to contracting issues
  - CFD model tool development & validation (Test Matrix)
  - Fundamental evaluation of process reliability and integration issues
  - Preliminary design, cost estimates, procurement, and test plans for identified solutions.
  - Continuation proposal
- Phase II: Implementation & evaluation (Mar 2006 – Sep 2007)
  - Final engineering, procurement & implementation
  - Testing/Evaluation
  - Final Reports
- Total Budget: \$1,300,000 DOE + \$1,600,000 cost share (55%)



# Critical Issues and Show-stoppers

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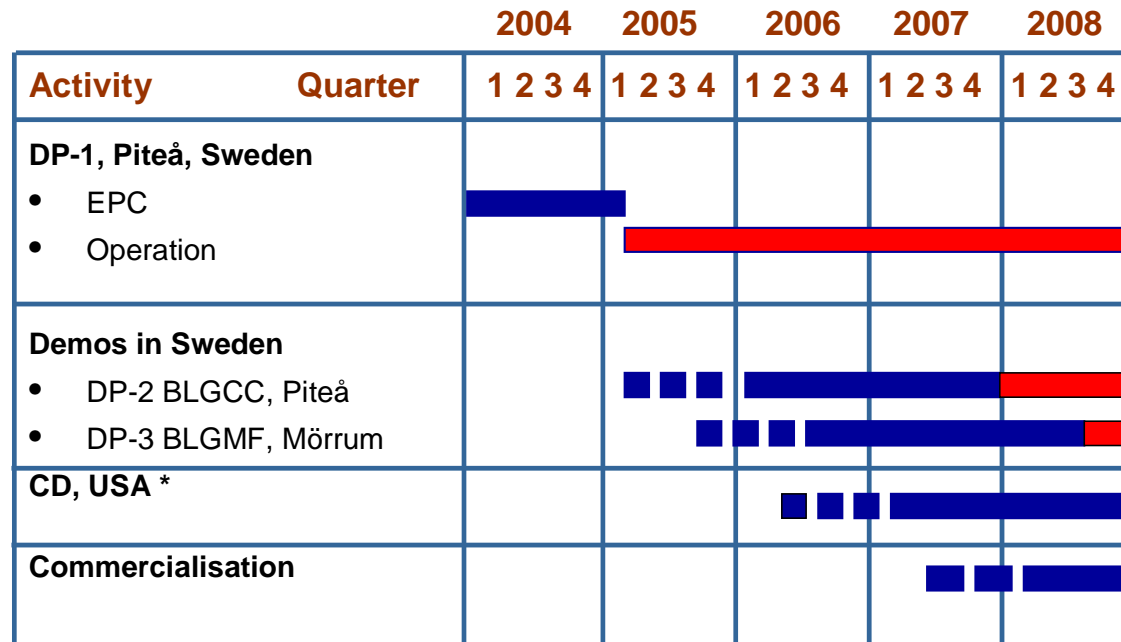
- HTBLG “booster” application is commercially proven operation at New Bern
- Recovery boiler replacement will require >98% availability
- High capital cost / lack of “green” incentives
- Ongoing successful operation and improvements to New Bern “booster” are critical factors to sustained development
- Show stoppers?
  - None for this project except... Loss of Weyerhaeuser management or DOE support
  - For BLGCC – lower cost recovery boiler option (i.e. HERB)



# Plans and Resources for Next Stage

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## Chemrec Time Schedule for Pressurized BLG Development



\*) A US CD-plant project is planned to start after evaluation of Swedish DP-1 operating results



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- Demo GL filtration at New Bern
- Demo SCT scrubber at New Bern
- +500-1000 tpd demo at US pulp mill



## *biomass program*

- BLG is a cornerstone technology for future integrated forest product biorefinery
- Commercial operation of Weyerhaeuser's New Chemrec gasifier offers a unique opportunity to advance HTBLG development
- Significant progress made on CFD model development
- Phase I testing just getting underway